

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Department of Physical Oceanography

Woods Hole, MA 02543

March 28, 1994

Dr. Steven Ramberg
ONR Code 322
Ballston Towers One
800 N. Quincy St.
Arlington, VA 22217-5660

AD-A277 821



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S F D

Re: Final Report for ONR Grant #N00014-89-J-1085

Dear Dr. Ramberg:

I am writing to provide a final technical report on ONR Grant N00014-89-J-1085 entitled "Gibraltar Exchange Measurements." The central purpose of this grant was to allow completion of the analysis of the Gibraltar Experiment current meter measurements made during 1985-86 and final publication of the results. During the course of this Grant, we have published a total of 10 papers on the Gibraltar exchange (as detailed on the attached list of publications) including a major review paper on the progress made in understanding strait dynamics as a result of the 2Gibraltar Experiment; two theoretical studies of two-layer exchange; two examples of the control exerted by the Strait of Gibraltar on long-term changes in Mediterranean circulation; as well as five papers describing the exchange processes and quantifying the mass, heat and freshwater fluxes through the Strait. With this month's acceptance by *Progress In Oceanography* of our summary paper on the nature of the exchange through the Strait of Gibraltar, I feel that all primary analyses and publications resulting from my Gibraltar work over the past decade are now complete.

I would like to thank the Office of Naval Research for their long-term support of the Gibraltar work. It was a bit more than 10 years ago when a group of scientists indicated our interests in developing an observational and theoretical study of the Gibraltar exchange to ONR. Encouraged by Dr. Dennis Conlon then an ONR Program Manager, we developed a major field program in the Strait during 1985-86. Analysis of the resulting measurements combined with development of theoretical models for two-layer exchange have led to marked improvements in our understanding of strait dynamics and exchange. Most notably, we have found the exchange to be only about half as large as had been previously thought; and the theoretically predicted exchange is remarkably within 15% of the observed exchange. Moreover, we have developed a parameterisation for the exchange that can be used in large-scale ocean circulation models which cannot properly resolve the Strait and we have developed a strategy for continuously monitoring the exchange. Throughout the field program and the analysis and publication phase of the Gibraltar Experiment, we have had stimulating scientific discussions with our colleagues on strait dynamics and the nature of the exchange. This interaction has been possible due to the farsighted policy at ONR to allow suitable time for analysis, discussion and publication of the results for a major field program.

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On behalf of the Gibraltar Experiment scientists, I would like to thank you and earlier program managers Drs. Dennis Conlon, Alan Brandt and Thomas Kinder for the opportunity to contribute to such an exciting and productive research program. If you require any additional information, I would be happy to provide it.

Sincerely yours,

Harry Bryden
(mte)

Harry Bryden
Principal Investigator

cc: Thomas Kinder (3)
Robert Tanner (1)
Director, Naval Research Laboratory (6)
Defense Technical Information Center (12)

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Publications on Gibraltar Exchange
by Harry L. Bryden during 1990-1994

- Kinder, T. H., and H. L. Bryden, 1990. The aspiration of deep waters through Straits. In: *The Physical Oceanography of Sea Straits*, L. J. Pratt, Editor, Kluwer Academic Publishers, Netherlands, pp. 295-319.
- Bryden, H. L., and R. D. Pillsbury, 1990. Measurement of flow through the Strait of Gibraltar. *Advances in Water Resources*, 12(2), 64-69.
- Kinder, T. H., and H. L. Bryden, 1991. Recent progress in strait dynamics. *Reviews of Geophysics*, Supplement, 617-631.
- Bryden, H. L., and T. H. Kinder, 1991. Steady two-layer exchange through the Strait of Gibraltar. *Deep-Sea Research*, 38(Supplement 1), S445-S463.
- Rohling, Eelco J., and Harry L. Bryden, 1992. Man-induced salinity and temperature increases in western Mediterranean deep water. *Journal of Geophysical Research*, 97(C7), 11,191-11,198.
- Kinder, T. H., and H. L. Bryden, 1992. Hydraulic control in the Strait of Gibraltar. *Advances en Oceanologie Mediterranene, Bulletin de l'Institut Oceanographique, Monaco*, Numero especial 11, 113-126.
- Bryden, H. L., 1993. Sill exchange to and from enclosed seas. In: Symposium, *Mediterranean Sea 2000*, September 1991, N. F. R. Della Croce, Editor, Istituto Scienze Ambientali Marine, Santa Margherita Ligure, 17-36.
- Rohling, E. J., and H. L. Bryden, 1994. Variations in sea level, freshwater budget, and hydrography in the Mediterranean. *Proc. Kon Ned. Akad.*, March 28, 1994.
- Macdonald, A. M., J. Candela and H.L. Bryden, 1994. An estimate of the net heat transport through the Strait of Gibraltar. In: *Seasonal and Interannual Variability of the Western Mediterranean*, P. LaViolette, Editor, American Geophysical Union, in press.
- Bryden, H. L., J. Candela, and T. H. Kinder, 1994. Exchange through the Strait of Gibraltar. *Progress In Oceanography*, in press.